Topics Covered:

- New Section 1000
- Modifications to existing BDM sections
- Status of Standard Drawings
BDM Section 1000
(ODOT LRFD Bridge Design Specifications)

- Complement to AASHTO LRFD Bridge Design Specifications
- Provides:
  - ODOT commentary
  - Exceptions to AASHTO provisions
  - Recommendations for optional provisions

**DRAFT VERSION** - Subject to change
### BDM Section 1000 (Continued)

- Article references parallel LRFD Specifications

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(Continued)

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LRFD Load Modifiers (η-factors)

Basic LRFD equation: \[ \sum \eta_i \gamma_i Q_i \leq \phi R_n \]

Where:

- \( \eta \) = Load Modifier for Importance, Redundancy and Ductility
- \( \gamma \) = Load Factor
- \( Q \) = Force effect
- \( N \) = Resistance Factor
- \( R_n \) = Nominal Resistance
LRFD Load Modifiers (η-factors)

Basic LRFD equation: \[ \sum \eta_i \gamma_i Q_i \leq \phi R_n \]

Where:

\( \eta = \text{Load Modifier for Importance, Redundancy and Ductility} \)
\( \gamma = \text{Load Factor} \)
\( Q = \text{Force effect} \)
\( N = \text{Resistance Factor} \)
\( R_n = \text{Nominal Resistance} \)
Load Modifier for Ductility ($\eta_D$)

For bridge components designed in accordance with AASHTO LRFD and the BDM:

$$\eta_D = 1.00 \text{ for all limit states}$$
Load Modifier for Redundancy ($\eta_R$)

- For non-redundant components:
  \[ \eta_R = 1.05 \text{ for the strength limit states} \]
  \[ \eta_R = 1.00 \text{ for all other limit states} \]

- For redundant components:
  \[ \eta_R = 1.00 \text{ for all limit states} \]
Load Modifier for Redundancy ($\eta_R$)

- Applied at the Component level
Non-Redundant Superstructures

3 or fewer girders regardless of spacing
Non-Redundant Superstructures

4 girders spaced at 12’-0” or greater
Non-Redundant Substructures

Single Column Piers
Non-Redundant Substructures

Two Column Piers
Non-Redundant Substructures

T-type Piers

Stem height-to-width = 3-to-1 or greater

Example:
- Height = 51.0 ft
- Width = 16.0 ft
- Ratio = 3.19
Redundancy

For additional information:

- NCHRP Report 458, **Redundancy in Highway Bridge Substructures**

- NCHRP Report 406, **Redundancy in Highway Bridge Superstructures**
Foundation Redundancy

- $\eta_R = 1.0$ for all foundations
- Non-redundant foundations → Reduce Resistance Factor (N) by 20%
- Pile Foundations:
  - $\leq 4$ piles per substructure unit
- Drilled Shaft Foundations:
  - Single shaft foundations
Load Modifier for Importance ($\eta_I$)

- For important bridges:
  \[ \eta_I = 1.05 \text{ for the strength limit states} \]
  \[ \eta_I = 1.00 \text{ for all other limit states} \]

- Important bridge criteria:
  - Design ADT $\geq 60,000$, or
  - Detour length $\geq 50$ miles, or
  - Span length $\geq 500$ ft.
Load Modifier for Importance ($\eta_I$)

- For “Less Important” bridges:
  - $\eta_I = 0.95$ for the strength limit states
  - $\eta_I = 1.00$ for all other limit states

- “Less Important” bridge criteria:
  - Design ADT $\leq 400$, and
  - Detour length $\leq 10$ miles
Load Modifier for Importance ($\eta_I$)

- For typical bridges:
  $$\eta_I = 1.00 \text{ for all limit states}$$
Load Modifier for Importance ($\eta_I$)

**Detour Length**: Shortest route available to emergency vehicles if the bridge is taken out of service
Load Modifier for Importance ($\eta_I$)

- Applied at the Global level
- Exceptions:
  - Decks on beams/girders
  - Railings
Protection of Structures
(LRFD Article 3.6.5)

Piers located within:
- 30.0 ft of roadway
- 50.0 ft of RR track

Require protection consisting of:
- Embankment
- 54.0 in. high barrier (<10.0 ft to obstruction)
- 42.0 in. high barrier (≥10.0 ft to obstruction)

Or, design for 400 kip impact load
Protection of Structures
(LRFD Article 3.6.5)

ODOT Requirement:

- Redundant Piers within 30.0 ft. of roadway:
  • Provide protection according to L&D Manual, Section 600
- Non-Redundant Piers within 30.0 ft. of roadway:
  • Design in accordance with LRFD Article 3.6.5
Protection of Structures
(LRFD Article 3.6.5)

ODOT Requirement:
- All Piers 25.0 ft. or less from centerline of RR tracks:
  - Wall type or T-type design, or
  - Protected by crashwall
Seismic Requirements

- Seismic Zone 1
  - $0.025 \leq \text{Acceleration coefficient} \leq 0.090$

- Extreme Event live load factor: ($\mathcal{E}_Q = 0.0$)

- Semi-integral & Integral Abutments:
  - Additional seismic restraint not required at abutments
  - Seismic restraint required at piers for multiple spans
Concrete Deck Design
(LRFD Article 9.7.2)

- Empirical Design Method
  - Bottom layer steel = 0.27 in²/ft
  - Top layer steel = 0.18 in²/ft
  - Spacing not to exceed 18.0 in.
Concrete Deck Design
(LRFD Article 9.7.3)

- Traditional Design
  - Calculation of force effects requires continuous beam analysis
  - ODOT minimum deck thickness will be retained:
    \[ T_{\text{min}} = (S+17)(12) \div 36 \geq 8\frac{1}{2} \text{ in.} \]
  - Spacing of Top and Bottom transverse mats shall coincide.
  - ODOT Design example will be included
Concrete Deck Design
(LRFD Article 9.7.3)

ODOT Design Aid:
- Provides required deck steel for:
  - Interior bays
  - Overhangs
- Assumptions:
  - Beam/Girder spacings: 7.0 ft. – 14.5 ft.
  - Uniform spacings
  - 4 or more beam/girder lines
  - 42” BR-1 concrete barrier (TL-5 loading)
Deck Overhang Design
(LRFD Article A13.4)

- ODOT Design Aid & Design Example
- Design Cases:
  
  1. Extreme Event ~ Transverse vehicle collision
     
     • Failure mode should be in barrier not deck
     
     • Collision Force = Smaller of \( \begin{cases} \text{Barrier Capacity} \\ 1.33 \times F_t \end{cases} \)
     
     • BDM will include table for strength of standard barrier shapes
Deck Overhang Design (LRFD Article A13.4)

Design Cases: (Continued)

2. Extreme Event ~ Vertical vehicle collision
   - Does not apply to concrete barriers
   - Check for punching shear for metal railings

3. Strength ~ HL-93 vehicle on overhang
Deck Overhang Design
(LRFD Article A13.4)

For Extreme Event design cases:

- Design overhang < 7’-0” → (LL = 0.00)
- Design overhang ≥ 7’-0” → (LL = 0.50)
Control of Cracking
(LRFD Article 5.7.3.4)

Spacing of mild reinforcement:

\[ s \leq \frac{700 \gamma_e}{\beta_s f_s} - 2d_c \]

Where:

\[ \beta_s = 1 + \frac{d_c}{0.7(h - d_c)} \]

- \( \gamma_e = 0.75 \) for decks and slabs
- \( d_c \) & \( h \rightarrow \) Deduct 1” M.W.S. from each
Foundation Recommendation
(BDM Section 201.2.6)

- Required with Structure Type Study
- Consists of:
  - General Foundation Type
  - Typed Boring Logs
  - Some lab test results:
    - Soil: Water content, particle size, liquid & plastic limits
    - Rock: RQD
Foundation Recommendation (BDM Section 201.2.6)

- Required with Structure Type Study
- Consists of:
  - **General Foundation Type**
  - Typed Boring Logs
  - Some lab test results:
    - Soil: Water content, particle size, liquid & plastic limits
    - Rock: RQD
Foundation Recommendation
(BDM Section 201.2.6)

- Foundation Type:
  - Deep foundations ~ Type Only!!
    (Size, no., length & loads not required)
  - Shallow foundations ~ Require estimates:
    • Bearing Loads/Pressures
    • Bearing Resistance
    • Settlement

Communication !!!
Spread Footings
(BDM Section 202.2.3.1)

- Design according to LRFD 10.6
- Site Plan → Footing elevations
- General Notes → Factored Pressure & Factored Resistance
- Foundation Report:
  - Footing Size
  - Predicted Settlements
  - Factored Bearing Resistances
- Adjust footing size as necessary during Detail Design
Pile Foundations
(BDM Section 202.2.3.2)

- Site Plan → Pile type, size & estimated length
- General Notes → Pile loads
- Adjust Estimated length & loads during Detail Design
Pile Foundations (Continued)

- ODOT Satisfied with current design
- ODOT’s LRFD Transition Objective:
  - Maintain similar number of required piles
  - Maintain similar estimated pile lengths
- Design variables include:
  - Factored Loads
  - Resistance Factors
  - Allowable Pile Loads
Pile Foundations (Continued)

Design Load ≤ Smaller of \[
\begin{cases}
\text{Geotech. Capacity} \\
\text{Structural Capacity}
\end{cases}
\]

• Geotechnical Capacity:
  • Resistance provided by soil or rock
  • Controls for Friction Piles

• Structural Capacity:
  • Resistance provided by pile
  • Controls for End Bearing Piles
Friction Piles
(BDM Section 202.2.3.2.b)

- Site Plan → Estimated Length
- General Notes → Ultimate Bearing Value
Friction Piles
(BDM Section 202.2.3.2.b)

Current BDM:
- Ultimate Bearing Value ($R_{ndr}$)
  \[ R_{ndr} = Q \cdot (F.S.) \]
  Where:
  - F.S. = 2.0 \left( F.S. = \frac{\bar{\gamma}}{\phi} \right) 
  - $Q$ = Total Unfactored Load

LRFD BDM:
- Ultimate Bearing Value ($R_{ndr}$)
  \[ R_{ndr} = \frac{\sum \eta_i \gamma_i Q_i}{\phi_{dyn}} \]
  (\eta_i = Load Factor
  $Q_i$ = Unfactored Load
  $N_{dyn}$ = Resist. Factor)
Friction Piles
(BDM Section 202.2.3.2.b)

\[ N_{\text{dyn}} = \text{Resistance factor for driven piles} \]

\[ \text{(LRFD Table 10.5.5.2.3-1)} \]

- Function of method used to determine driving criteria (i.e. Blow Count)
  - Static Load Tests \( (N_{\text{dyn}} = 0.55 - 0.90) \)
  - Dynamic Load Tests \( (N_{\text{dyn}} = 0.65) \)
  - Wave equation \( (N_{\text{dyn}} = 0.40) \)
  - Gates Formula \( (N_{\text{dyn}} = 0.40) \)
  - ENR Formula \( (N_{\text{dyn}} = 0.10) \)
Friction Piles  
(BDM Section 202.2.3.2.b)

\[ N_{\text{dyn}} = \text{Resistance factor for driven piles} \]

\[ (LRFD \ Table \ 10.5.5.2.3-1) \]

- Function of method used to determine driving criteria (i.e. Blow Count)
  - Static Load Tests \((N_{\text{dyn}} = 0.55 - 0.90)\)
  - Dynamic Load Tests \((N_{\text{dyn}} = 0.65)\)
  - Wave equation \((N_{\text{dyn}} = 0.40)\)
  - Gates Formula \((N_{\text{dyn}} = 0.40)\)
  - ENR Formula \((N_{\text{dyn}} = 0.10)\)
Friction Piles
(BDM Section 202.2.3.2.b)

Another look:

\[ R_{ndr} = \sum \frac{\eta_i \gamma_i Q_i}{\phi_{dyn}} \]

and remember… \( \left( \frac{F.S. = \overline{\gamma}}{\phi} = 2.0 \right) \)

- \( \overline{\gamma} > 1.0 \) (e.g. \( \gamma_{DC}=1.25; \ (DW=1.50; \ (LL=1.75) \)
- Q is larger (HL-93 includes truck & lane)
- If \( N_{dyn} \) is too small, \( R_{ndr} \) will be larger and…
  - More Piles & Longer Piles
Friction Piles
(BDM Section 202.2.3.2.b)

**ODOT Modification:**
For piles driven according to C&MS 507 & 523:

\[ N_{\text{dyn}} = 0.70 \]
# Friction Piles
(BDM Section 202.2.3.2.b)

<table>
<thead>
<tr>
<th>Pipe Pile Diameter</th>
<th>Maximum $R_{ndr}$</th>
<th>H-pile Size</th>
<th>Maximum $R_{ndr}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>12 inch</td>
<td>250 kips</td>
<td>HP10x42</td>
<td>443 kips</td>
</tr>
<tr>
<td>14 inch</td>
<td>300 kips</td>
<td>HP12x53</td>
<td>543 kips</td>
</tr>
<tr>
<td>16 inch</td>
<td>390 kips</td>
<td>HP14x73</td>
<td>757 kips</td>
</tr>
</tbody>
</table>

Increase in Maximum $R_{ndr}$ attributed to:
- Structural capacity and minimum pile thickness per C&MS 507.06.
- Drivability analysis required by LRFD Article 10.7.8 to verify Ultimate Bearing Value.
Friction Piles
(BDM Section 202.2.3.2.b)

**Estimated Pile Length:**

\[ R_{ndr} = R_S + R_P \]

Where:

\[ R_{ndr} = \frac{\sum \eta_i \gamma_i Q_i}{\phi_{dyn}} \]

- \( R_S \) = Unfactored side resistance calculated by Static Methods
- \( R_P \) = Unfactored tip resistance calculated by Static Methods
Piles Driven to Refusal on Bedrock (BDM Section 202.2.3.2.a)

- Estimated Length → Elevation at top of rock core at closest boring
- General Notes → Total Factored Load
  (Highest loaded pile at each substructure)

\[ \sum \eta_i \gamma_i Q_i \leq \phi R_n = R_r \]
### Piles Driven to Refusal on Bedrock (BDM Section 202.2.3.2.a)

**Maximum Factored Structural Resistance ($R_{r\text{max}}$)**

<table>
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<th>H Pile Size</th>
<th>$R_{r\text{max}}$</th>
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<tr>
<td>HP10X42</td>
<td>310 kips</td>
</tr>
<tr>
<td>HP12X53</td>
<td>380 kips</td>
</tr>
<tr>
<td>HP14X73</td>
<td>530 kips</td>
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Piles Driven to Refusal on Bedrock
(BDM Section 202.2.3.2.a)

$R_{r_{\text{max}}}$ Assumptions:
- Axially loaded pile with negligible moment
- Negligible section loss due to deterioration
- $F_y = 50$ ksi
- Severe driving conditions
- Pile fully braced along its length
Piles Driven to Refusal on Bedrock (BDM Section 202.2.3.2.a)

$R_{r_{\text{max}}}$ Assumptions:

- Axially loaded pile with negligible moment
- Negligible section loss due to deterioration
- $F_y = 50$ ksi
- Severe driving conditions
- Pile fully braced along its length

$R_{r_{\text{max}}}$ for Capped Pile Piers or Piles in scour zone should be calculated separately.
Standard Bridge Drawings

Affected Drawings:
- Continuous Slab
- Single Span Slab
- Barriers
- Approach Slab
- Capped Pile Pier
- Capped Pile Abutment
- Non-composite Box Beam Design Data Sheets
Standard Bridge Drawings

Affected Drawings:
- Continuous Slab
- Single Span Slab
- Barriers
- Approach Slab
- Capped Pile Pier
- Capped Pile Abutment
- Non-composite Box Beam Design Data Sheets
Miscellaneous Items

- The stiffness contribution of continuous concrete barriers, curbs, sidewalks should **ALWAYS** be ignored.
- The “Optional” live load deflections limits are **NOT** Optional.
- The “Optional” span-to-depth ratios are **NOT** Optional.
Protection of Users (LRFD Article 2.3.2.2.2)

- For routes with design speed > 45 mph:
  Separate vehicle & pedestrian traffic with crash-tested barrier

- For routes with design speed ≤ 45 mph:
  Separate vehicle & pedestrian traffic with crash-tested barrier when pedestrian railing is not crash worthy.
Dynamic Load Allowance  
(LRFD Article 3.6.2)

For Deck Joints:
- IM = 125% static effect of design truck
- IM = 100% static effect of design tandem
Uniform Temperature
(LRFD Article 3.12.2)

- AASHTO LRFD allows two methods:
  - Procedure A – Same as Standard Spec.
  - Procedure B – Calibrated for specific bridge types

- ODOT recommends Procedure A
  - Cold Climate
Spiral Reinforcement
(LRFD Article 5.7.4.6)

\[
\rho_s \geq 0.45 \left( \frac{A_g}{A_c} - 1 \right) \frac{f'_c}{f_y}
\]

- For columns, this provision only applies when at the Strength Limit State:
  \[
  \frac{\text{Axial Capacity}}{\text{Axial Load}} < 1.5
  \]
- Otherwise use #4 spiral with 4.5 in. pitch
Prestressed concrete stress check:

- **Service III Limit State:**
  - (LL = 0.80)

- Assume severe corrosive environment:
  - Includes exposure to deicing salts

- Stress Limit = \(3 \sqrt{f_c'}\) (psi)
Questions?